such factors are typically cited as relative contraindications to CEA instead of carotid stenting. The findings of our study do suggest that patients who require prolonged operation for hemostasis or other reasons may benefit if possible from intermittent release of intraoperative retraction in order to prevent temporary cranial nerve palsy and that surgeons should exercise particular caution in patients who require early reoperation after CEA.

Author Disclosures: K. M. Bennett: None; **J. E. Scarborough:** None; **C. K. Shortell:** None.

Surgeon Radiation Dose During Complex Endovascular Procedures

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Introduction: Surgeon radiation dose during complex endovascular procedures (CEPs) has not been well studied. We sought to characterize radiation exposure to surgeons during CEPs based on procedure type, operator position, level of operator training, upper vs lower body exposure, and the addition of protective shielding.

Methods: Optically stimulable, luminescent nanoDot (Landauer Inc) detectors were used to measure radiation dose prospectively to surgeons during CEPs. NanoDot dosimeters were placed outside the lead apron of the primary and assistant operator at the left upper chest and left lower pelvis positions. For each case, procedure type, reference air kerma (RAK), kerma area product (KAP), the relative position of the operator, level of training of the fellow, and presence or absence of external additional shielding devices were recorded. Three positions were assigned on the right hand side of the patient in decreasing relative proximity to the flat panel detector (FPD) as A, B, and C, respectively. Position A (main operator) was closest to the FPD. Position D was on the left side of the patient at the brachial access site. NanoDots were read using a Microstar II medical dosimetry system (Landauer Inc) after every procedure. The nanoDot dosimetry system was calibrated for scattered radiation in an endovascular suite with a NIST-traceable solid state radiation detector (Piranha T20, RTI). Comparative statistical analyses of nanoDot dose levels between categories was performed using analysis of variance with Tukey pairwise comparisons. Bonferroni correction was used for multiple comparisons.

Results: There were 415 nanoDot measurements with the following case distribution: 16 thoracic endovascular aortic repairs or endovascular aneurysm repairs, 18 fenestrated endovascular aneurysm repairs (FEVARs), 13 embolizations, 41 lower extremity, 10 fistulograms, and 13 viscerals. The mean operator dose for FEVARs was statistically higher than for other case types ($P < .03$), 15 μSv at position A and 11 μSv at position B. For all case types, positions A (8.7 ± 2.7 μSv) and D (14.4 ± 7.8 μSv) received statistically higher effective doses than B (3.9 ± 2.7 μSv; $P < .001$ or C (0 mGy). However, the mean operator dose for position D was not statistically different from position A. The addition of the lead skirt significantly decreased the lower body dose (33 ± 3.4 μSv to 6.3 ± 3.3 μSv) but not the upper body dose (6.5 ± 3.3 μSv to 5.7 ± 2.2 μSv). The use of ceiling-mounted shielding did not affect the nanoDot dose. There was no difference in the operator dose observed based on level of training when the fellow was in position A. KAP was the better predictor of operator radiation dose compared with RAK. The mean KAP for all cases was 330 $Gycm^2$, and the regression coefficient for operator dose to KAP was 0.021 ± 0.003 μSv/$Gycm^2$ for position A and 0.015 ± 0.003 μSv/$Gycm^2$ for B.

Conclusions: Surgeon radiation dose during CEPs depends on case type, operator position, and table skirt use, but not on the level of fellow training. On the basis of this data, the primary operator could perform ~12 FEVARs per week and have an annual dose of <10 mSv, which would not exceed lifetime occupational dose limits during a 35-year career. Excluding FEVARs with the above case mix, the primary operator could perform ~40 CEPs per week and stay within regulatory limits. With practical case loads, operator doses are relatively low and unlikely to exceed occupational limits.

Author Disclosures: M. L. Kirkwood: None; **J. Guild:** None; **G. Arbique:** None; **J. A. Anderson:** None; **R. J. Valentine:** None; **C. Timaran:** None.

Antiplatelet and Statin Treatment Is Not Associated With Reduced Myocardial Infarction After High-Risk Vascular Procedures

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Introduction: Medical management (MM) with antiplatelet (AP) and statin therapy is recommended for most patients undergoing vascular surgery. We evaluated the preoperative use of these on postoperative myocardial infarction (MI) in patients undergoing high-risk procedures within the Vascular Quality Initiative (VQI).

Methods: We studied VQI patients undergoing elective suprainguinal (n = 3039) and infrainguinal bypass (n = 8323) and open abdominal aortic aneurysm repair (n = 3007) from 2005 to 2014. We examined the use of MM (AP or statin, or both) on postoperative MI and postoperative death. Multivariable analyses were performed to identify factors associated with preoperative MM use as well as and MI and MI/death rates across procedures and cardiac risk strata (using Vascular Study Group of New England cardiac risk criteria).

Results: Overall, most patients were on both AP and statin at the time of surgery (56% vs 12% neither agent, 19% AP only, 17% statin only), and MM was similar across procedure groups. Rates of MI were similar despite MM strategy, with slightly higher rates in patients on both agents (neither AP or statin, 2.4%; AP only, 2.6%; statin only, 2.8%; both, 3.7%; $P = .003$). MI increased with cardiac risk (1.8% vs 3.8% vs 6.5% for low, medium, and high risk; $P < .01$). When MI was stratified by cardiac risk, MM did not reduce MI rates and was slightly higher for patients on both agents (Fig). After multivariable adjustment for MI, MM was not associated with reduced MI compared with those on neither medication (AP only: odds ratio [OR], 1.0; 95% confidence interval [CI], 0.6-1.5; statin only: OR, 0.9; 95% CI, 0.5-1.4; both agents, OR, 1.0; 95% CI, 0.7-1.5; $P > .05$ for all). Findings were similar for combined outcome of MI/death. Finally, analysis demonstrated that APs and statins were used more often in patients with known cardiovascular risk factors.

Conclusions: These data confirm that MI events are highly associated with a patient's estimated cardiac risk. However, lack of MM did not result in higher rates of MI. It appears that higher-risk patients are currently selected for MM in VQI but that this is not associated with reduced postoperative MI or MI-related mortality.

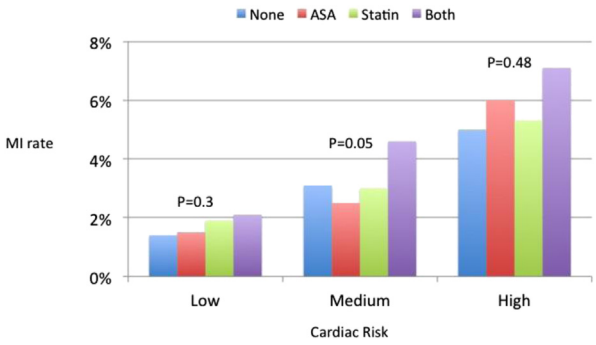

Fig. Rates of myocardial infarction (*MI*) by treatment with antiplatelet and statin medications across cardiac risk. *ASA*, Acetylsalicylic acid.

Author Disclosures: R. R. DeMartino: None; **A. W. Hoel:** None; **A. W. Beck:** None; **J. W. Hallett:** None; **S. Arya:** None; **G.H. Upchurch:** None; **J. L. Cronenwett:** None; **P. P. Goodney:** None.

Heart Rate Is Not a Reliable Predictor of Adverse Cardiac Outcomes or Mortality After Major Elective Vascular Surgery

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Introduction: Arrival heart rate (AHR) and heart rate control (HRC) are known indicators of cardiovascular complications after cardiac surgery, but there is little evidence of their role in predicting outcome after major vascular surgery. The purpose of this study was to determine whether AHR and HRC are predictive of mortality or major adverse cardiac events (MACE) after elective vascular surgery in the Vascular Quality Initiative (VQI).

Methods: The VQI data set was used to perform a retrospective analysis of patients undergoing elective infrainguinal bypass (IIB), suprainguinal bypass (SIB), and open abdominal aortic aneurysm (AAA) repair (oAAA). MACE was defined as any postoperative myocardial infarction (POMI), dysrhythmia, or congestive heart failure. Controlled HR was defined as a HR of <75 beats/min upon operating room arrival. HRC was determined by taking the highest intraoperative HR-AHR. Procedure-specific MACE

models were applied to risk-stratify patients. β-Blocker (BB) status of none vs acute (0-30 days preoperatively) vs chronic (>30 days preoperatively) was evaluated, and a Bonferroni correction with a $P < .002$ was used to declare any result significant at a 5% error rate. Logistic regression generalized estimating equations and linear mixed models were used with MACE as the outcome, and AHR/HRC, BB status, and the interaction between AHR/HRC and BB status as fixed factors.

Results: A total of 13,141 elective patients were reviewed (IIB: n = 8155 [62%]; SIB: n = 2629 [18%]; oAAA: n = 2629 [20%]). The raw nonrisk adjusted rates of MACE and 30-day mortality were IIB: MACE, 9.8% (n = 633) and 2.0% (n = 126); SIB, 15.7% (n = 263) and 2.6% (n = 43); and oAAA, 21.7% (n = 486) and 3.3% (n = 73). Rates of any preoperative BB exposure were IIB, 66.5% (n = 5412); SIB, 57% (n = 1342); and oAAA, 74.2% (n = 1949). Association of AHR and HRC with outcomes was variable across patients and procedures. AHR of <75 beats/min was associated with increased risk of POMI for IIB patients across all cardiac risk strata (odds ratio [OR], 1.4; 95% confidence interval [CI], 1.03-1.9; $P = .03$), whereas AHR >75 beats/min was associated with increased risk for dysrhythmia (OR, 2.4; 95% CI, 1.6-3.6; $P = .0001$) and 30-day death (OR, 2.0; 95% CI, 1.3-3; $P = .001$) in moderate-risk and high-cardiac-risk patients. These HR effects disappeared when controlling for BB status. SIB had no association between AHR and 30-day mortality; however, AHR >75 beats/min was associated with an increased risk of congestive heart failure congestive heart failure across all cardiac risk strata (OR, 2.2; 95% CI, 1.2-3.8; $P = .007$). These effects also disappeared when controlling for BB exposure. No association with HR and MACE outcome was noted among oAAA patients irrespective of BB status. However, 30-day mortality was increased (OR, 1.9; 95% CI, 1.03-3.4; $P = .04$) for patients with AHR >75 beats/min. This association was sustained when controlling for acute but not chronic BB status. HRC was analyzed among all three operations, and inconsistent associations with MACE or 30-day mortality were detected.

Conclusions: HR is highly confounded by patient presentation, operative variables, and BB therapy. The discordance between cardiac risk and HR as well as the lack of consistent correlation to outcome makes this an unreliable predictor. The VQI has elected to discontinue collecting heart rate data nationally given the lack of sufficient data to suggest its importance as an outcome measure.

Author Disclosures: S. T. Scali: None; **D. Neal:** None; **D. J. Bertges:** None; **J. Eldrup-Jorgensen:** None; **J. L. Cronenwett:** None; **A. W. Beck:** None.

Table. High-sensitivity C-reactive protein (*hsCRP*), B-type natriuretic peptide (*BNP*), and other predictors of major adverse limb events (*MALE*) and major adverse cardiovascular events (*MACE*)

	HR (95% CI)	P *value*
MALE at 2 years		
Overall cohort		
hsCRP	1.1 (1.0-1.2)	.059
Male gender	1.6 (1.0-2.6)	.062
Chronic limb ischemia	1.8 (1.1-3.1)	.020
Outflow procedure	1.8 (1.1-3.2)	.033
Procedure specific model		
Endovascular		
hsCRP	1.2 (1.0-1.4)	.016
Outflow procedure	2.7 (1.4-5.2)	.004
Obesity (BMI >30)	2.5 (1.3-4.8)	.006
Open surgical		
Male gender	3.4 (1.5 -7.8)	.003
Hyperlipidemia	2.4 (1.2-5.1)	.016
Vein bypass conduit (vs prosthetic)	3.5 (1.6-7.6)	.002
MACE at 2 years		
Overall cohort		
BNP	1.02 (1.0-1.04)	.018
Coronary artery disease	2.2 (0.9-5.4)	.075
Procedure specific model		
Endovascular		
Age	1.05 (1.00-1.09)	.033
Heart failure	10.6 (2.0-56.9)	.006
Open surgical		
BNP	1.03 (1.01-1.04)	.003

BMI, Body mass index; *CI,* confidence interval; *HR,* hazard ratio; *MI,* myocardial infarction.

We used Cox proportional-hazards models to assess univariate and multivariable covariates. HRs and 95% CI were calculated for each factor by univariate analysis. All prognostic factors with $P < .10$ were included into a Cox multivariate analysis with back-wards entry to determine independent predictors.

Biochemical Markers in Patients With Peripheral Vascular Disease: Comparison Between Endovascular and Open Reconstructions

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Introduction: Previously, our group reported on the preoperative markers, high-sensitivity C-reactive protein (hsCRP), and B-type natriuretic peptide (BNP) and their ability to predict future major adverse limb events (MALE) and major adverse cardiovascular events (MACE) after lower extremity endovascular interventions. Others have reported the predictive power of these biomarkers for adverse outcomes in endovascular cohorts or open surgical reconstructions. No literature currently addresses the use of these biomarkers while comparing revascularization strategies or while examining autologous and prosthetic reconstructions in surgical bypasses.

Methods: We retrospectively examined patients who underwent elective endovascular intervention or open surgical reconstruction for lower extremity peripheral arterial occlusive disease between January 1, 2007, and December 31, 2013. All procedures were performed by a single operator. Patients' preprocedural levels of hsCRP and BNP were measured, and they underwent postprocedural ankle-brachial index measurement and duplex ultrasound imaging or contrast angiography. Examined outcomes included MALE (composite end point of target vessel revascularization, limb amputation, or disease progression) and MACE (stroke, myocardial infarction, or death) occurring by 24 months. The relationship between baseline hsCRP and BNP levels and time to the MALE and MACE was examined by univariate and multivariate Cox proportional hazard regression analyses.

Results: The analysis included 245 limbs in 200 patients (median age [interquartile range], 63 [53-71] years), with 156 limbs receiving endovascular revascularization and 89 limbs receiving surgical reconstruction. The surgical cohort was composed of a greater proportion of: men (62% vs 42%; $P = .01$), limbs with critical limb ischemia (60% vs 17%; $P < .01$), and outflow procedures (82% vs 39%; $P < .01$) compared with the endovascular cohort. Preprocedural levels of hsCRP and BNP did not differ between surgically and endovascularly treated limbs (hsCRP, 0.57 [0.26-1.18] vs 0.43 [0.22-0.96] mg/dL; $P = .21$; BNP, 43 [18-112] vs 44 [18-82] pg/mL; $P = .66$). When endovascularly treated limbs were examined in isolation, multivariate analysis demonstrated that higher hsCRP levels were significantly associated with MALE (hazard ratio [HR], 1.2; 95% confidence interval [CI] 1.0-1.4; $P = .02$; Table). In surgical reconstructions, neither BNP nor hsCRP was associated with MALE; however, the use of a vein bypass conduit (vs prosthetic reconstruction) significantly predicated MALE (HR, 3.5; 95% CI, 1.6-7.6; $P < .01$). HsCRP failed to associated with MACE in endovascularly or surgically treated limbs. However, elevated BNP levels associated with MACE in the surgical cohort (HR, 1.03; 95% CI, 1.01-1.04; $P < .01$) but not in those receiving endovascular intervention.

Conclusions: Elevated hsCRP levels predicted inferior results in endovascular reconstructions, whereas elevated BNP levels associated with impaired long-term survival in patients with surgical revascularizations. Additional studies should use biochemical markers to further stratify outcomes after both types of vascular interventions as a means to elucidate how biomarkers can best assist clinical decision-making for outcome improvement.

Author Disclosures: P. A. Stone: None; **J. E. Campbell:** None; **S. N. Thompson:** None; **D. Williams:** None; **Z. AbuRahma:** None; **L. Grome:** None; **H. Schlarb:** None; **M. John:** None; **A. F. AbuRahma:** None.

Finite Element Analysis of a Balloon-Expandable Stent and Superior Mesenteric Arterial Wall Interaction

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Introduction: An iCAST covered balloon-expandable stent (Maquet Getinge Group, Hudson, NH) has been used in the superior mesenteric artery (SMA) to treat a variety of pathology and most recently for visceral stenting in fenestrated endovascular aortic repair (FEVAR). Stenting has primarily been investigated by bench studies involving finite element analysis in the coronaries; however, further explanation of the mechanical behavior has not been performed. This study examined Atrium stent expansion using a pseudoballoon and then a second simulation expanding the stent into a theoretical SMA.